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Review

Mediterranean Raisins/Currants as Traditional Superfoods: Processing, Health Benefits, Food Applications and Future Trends within the Bio-Economy Era

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Abstract: This review elaborates on the significance of Mediterranean raisins, focusing particularly on indigenous Greek varieties (e.g., Zante currants) as a previously overlooked traditional food, currently brought on the spotlight, resulting from the increased consumers' awareness to improve wellness through diet modification. Recent studies on the effect of processing steps on final quality, along with findings on the potential health benefits raisins and currants elicit, are also presented. The development of novel functional food products to further exploit the nutritional value and the bioactive compounds of raisins is evidenced in view of indicating potential food industry applications. Moreover, valorization options of waste and by-product streams obtained from processing facilities are also proposed. Conclusively, raisins and currants should be further enhanced and incorporated in a balanced diet regime through the inclusion in novel foods formulation. Evidently, both the processing of the onset material and side-streams management, are essential to ensure sustainability. Hence, the article also highlights integrated biorefinery approaches, targeting the production of high-value added products that could be re-introduced in the food supply chain and conform with the pillars of bio-economy.

Keywords: zante currants; raisins; polyphenols; food product development; health benefits; bioactive compounds

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1. Introduction

The global increase in the prevalence of several chronic diseases has caused an inverse correlation to consumers' awareness regarding their dietary habits as reflected by the emerging demand for foods with potential health-promoting benefits. For instance, the incidence of diabetes, cardiovascular and neurodegenerative diseases among others has been linked to food consumption attitude. In particular, obesity has been outlined by the World Health Organization (WHO) as the epidemic of the last decades; in 2016 more than 1.9 billion adults were found to be overweight, whereas 13% of the world adult population (aged older than 18 years) were obese, based on the measurements of body mass index (BMI) [1]. Obese individuals with high BMI are also in the group of elevated risk of cardiovascular diseases (CVDs), the leading cause of death worldwide. Increased BMI values also relate to degenerative diseases and musculoskeletal disorders (e.g., osteoarthritis, Alzheimer's disease, and dementia) and some types of cancer. Diet modification plays a pivotal role to prevent obesity, thereby reducing the risk of CVDs and cognitive function towards protecting heart and brain health.

Regardless the molecular and genetic factors, the incidence of neurodegenerative diseases in ageing population is also affected by the diet. For instance, significant research has focused to elucidate the mechanistic action of polyphenols with neuroprotective potential via the consumption of micronutrients and secondary plant metabolites [2,3].

Metabolic syndrome is a combination of at least three factors that appear together, leading to high risk of CVD and type 2 diabetes. Changes in dietary patterns and lifestyle to prevent and manage metabolic syndrome, are associated with the inclusion of functional foods and dietary supplements with bioactive compounds [4]. Specific components obtained through diet can mediate the metabolic syndrome by supporting homeostatic mechanisms and preventing oxidative stress [5].

Functional foods have demonstrated an emerging demand as consumers' perception is changing towards healthier and sustainable diet patterns. Functional foods contain several compounds that positively affect health or reduce the risk of disease; still the claimed health benefits should be accompanied by scientific evidence [6,7]. Reduced sugar and low-fat products or products enriched with fiber, prebiotics and vitamins constitute some examples of functional foods formulated after processing. Nonetheless, it is quite frequent that consumers are not willing to change their eating routine or they might be skeptical on food processing therefore focus is given on implementing nutrient dense natural foods.

Within this context significant attention has been given lately on the concept of superfoods, one of the categories of functional foods. Regardless the fact that consumers worldwide have embraced the concept of functional foods and superfoods, with respect to health benefits and prevention of diseases, an official and universal definition has not been recognized by regulatory authorities [8]. Worldwide superfoods market is projected to increase by 201.67 billion US$ by 2023, demonstrating an increase from 2019, whereby vitamins occupy the largest share of the market, followed by fibers and minerals [9].

Several reviews have described superfoods as natural or minimally processed foods, with enhanced nutritional value and high concentration of bioactive compounds that impart health benefits and enhance wellness [8,10]. Polyunsaturated fatty acids (ω-3 and ω-6), vitamins, minerals, probiotics, antioxidants, and polysaccharides constitute some biomolecules found in superfoods with evidenced health benefits. These biologically active compounds can act on several target sites, and induce reduction in the risk of CVD, cancer and type 2 diabetes, potential prevention of degenerative diseases, reduction in circulating blood cholesterol, immune-stimulation, changes in oxidative stress, and the modulation of gastrointestinal microbiota, among others [11].

On the other hand, traditional foods have been identified in several countries worldwide, distinguished by an indigenous biodiversity, deriving from interactions of ecological and societal environments [12]. These might include exotic fruit, cereals, and fermented products, among others. The growing interest for superfoods prompted regional stakeholders, including researcher communities and food manufacturing industries, to direct and reconsider traditional foods that have been overlooked for years following an evolving modern lifestyle. As such, super-fruit e.g., blueberries, acai berries, goji berries and Corinthian and Zante currants have significantly ascended in the consumers' preference, within the context of redirecting our nutrition towards traditional foods [13]. As an example, the anthocyanins contained in acai berries have demonstrated anticarcinogenic and neuroprotective effects and relate to cardiovascular protection and were incorporated in nano-emulsions for further food application [14]. Worth noting is the fact that the inclusion of fresh or dried fruit as a source of functional compounds is a rather novel concept to coincide with boosting demand for novel and functional foods development.

The consumption of raisins, along with other dried fruit, is flourishing as they can be directly consumed or incorporated into a variety of foodstuffs, exhibiting high nutritional value. In the context of health benefits, raisins have been evaluated for their antioxidant properties and polyphenol content, the reduction in postprandial insulin response, the reduction in cholesterol and protection against CVD, the protective effect on colon cancer etc. [15,16]. Likewise, their inclusion in the development of functional foods will enable easier access on the protective health benefits that the bioactive compounds can impart.

Several reviews have reported in detail the developments in pre-treatment methods and the production of raisins, along with the effect on quality characteristics [17–19]. Therefore, the aim of this review is to elaborate recent updates on the production, the nutritional value, and the effect on human health of raisins with particular focus on indigenous varieties (e.g., Zante currants). On top of that, recent achievements on the development of innovative food applications to include raisins and benefit from their functional and bioactive compounds will be assessed. Additionally, the possibility to include and combine food formulation through a novel biorefinery approach will be demonstrated, incorporating also the circular valorization of side-streams obtained during raisins and currants processing. The optimal scenario would be to mitigate wastewaters and generate novel products that could be re-introduced in the food supply chain and impart health benefits but also conform with the pillar foundations of circular economy and bio-economy.

2. Production and Processing Of Raisins: Effect on Final Quality

Grape constitutes one of the dominant fruit crops worldwide; its global production increased from 75.1 mt in 2016 to 77.8 mt in 2018 [20]. Approximately 57% of the total production is used in wine making, 36% for table grape and a share of 7% is further treated for dried grape, yielding an annual production of 1.2 mt of dried raisins for 2018/19, demonstrating a 5% increase from 2017/18 based on market and trade data obtained from the United States Department of Agriculture (USDA) [21]. The main raisin producers are Turkey, USA, China, and Iran, contributing to approximately 73% of the global raisin production for 2018/19 [22]. Raisins, sultanas and currants are the three categories of dried grapes. More specifically, 95% of the total production refers to Thompson seedless variety whereas 1.5% corresponds to black Corinthian currants [17], with more than 80% deriving from Greek production, representing a 3% of the global dried vine production [23].

Indigenous Greek dried grapes production is classified on the following dominant varieties: Zante currants obtained from black Corinth grapes (*Vitis vinifera* L., var. *Apyrena*), the Corinthian currants Vostizza and Sultana or "Sultanina" from the cultivation of *Vitis vinifera* L., cv. Sultanina [24,25]. Specifically, Zante currants are cultivated without irrigation and processed to dried product in the island of Zakynthos, using *Vitis corinthica* grapes [24]. Both Zante and Vostizza currants are characterized as a protected designation of origin (PDO) product [23].

The process of raisin production from grapes includes three main steps, pre-treatment, drying, and post-drying (Figure 1). The pre-treatment step is optional but is usually employed to remove the waxy layer formed on the skin of the grape during the ripening stage, providing a barrier to permeability and water diffusion [18,26]. On top of that, pre-treatment steps have been shown to increase the dehydration rate during drying process and enhance the quality of the final product [19,27].

Pre-treatment methods include physical and chemical methods [18,19]. Chemical methods entail the application of an alkaline solution (e.g., NaOH, K_2CO_3, and $NaHCO_3$) combined with olive oil, ethyl oleate solution [24,27,28]. Gas treatments (CO_2, SO_2, and O_3) have been also reported as a process of chemical treatment to modify the permeability of cell membranes on fruit [29].

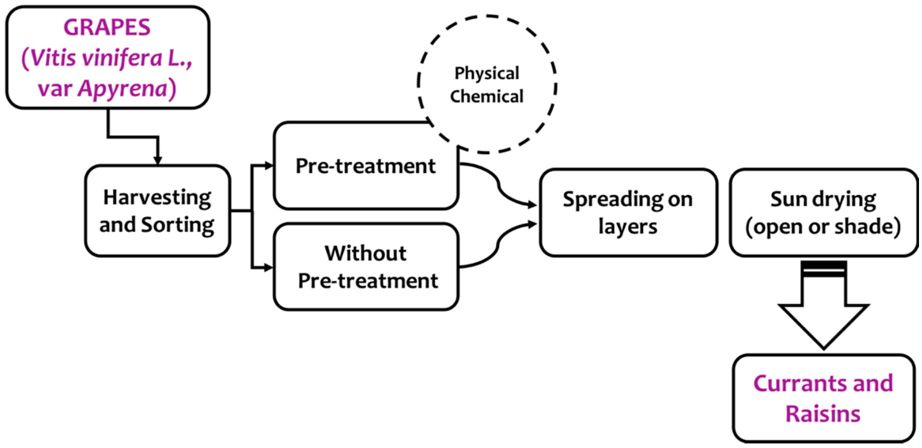

Figure 1. Grapes processing steps for currants and raisins production [18,19,24].

With respect to physical treatments, they are differentiated between thermal and non-thermal applications, including blanching, abrasive processes, ultrasound, pulsed electric fields and hydrostatic pressure [19]. Apart from softening the waxy layer of grapes, physical processes like blanching or microwave irradiation, entail the inactivation of enzymes, such as pectinmethylesterase (PME), peroxidase (POD), and polyphenol oxidase (PPO). Enzymatic activity leads to browning or changes in the phenolic content and antioxidant activity [17]. Blanching is performed by immersion in hot water, acid or alkaline solutions, steaming or microwave for designated time periods. Treatment with sulfite solutions or sulfitation is carried out using $K_2S_2O_5$, $Na_2S_2O_5$, and $NaHSO_3$, and prevents enzymatic browning via the inactivation of PPO.

In the case of *Zante* currants, pre-treatment methods are not applied as it is a traditional and naturally produced food, although some pre-treatment steps with sulfitation may be employed for the Sultanina in Crete to prevent microbiological spoilage after drying [24,30].

Drying of grapes is performed until the final moisture content is approximately 13% in the obtained product [31]. Several ways have been reported for dehydration, the dominant ones being natural sun drying, solar drying, shade drying and mechanical (or conventional) drying. Sun and solar drying have been the methods traditionally employed in the production of raisins. Natural open sun drying is a low-cost method, performed by placing grapes in thin layers on the ground or hanging on the vines, directly exposed to sunlight, for a period of up to 3 weeks [18,24]. Regardless the simplicity of these methods, the reliance on weather conditions might trigger microbial spoilage and insect infections. Application of solar drying is relying on the utilization of solar energy, performed via direct, indirect, and mixed types of driers [32,33]. Jairaj et al. [32] stressed out that wide acceptance of solar driers is hindered by the high initial capital cost, specifically for small and medium scale producers, regardless the short payback time that renders the process economically feasible and environmentally benign.

Shade drying constitutes another natural way to remove water from raisins, also referred to as natural rack dryers, commonly used in China, Australia, and India [18]. Grapes can be placed either on trays, on the ground or hanging on the vine and subsequently covered so that ambient air circulates to dry the fruit. A reduction in drying time of raisins (equal to 43%) has been reported using shade drying compared to open sun drying [34]; however, the effect on the final quality and the antioxidant properties is indistinctly affected by sanitary conditions [18,23].

Mechanical or conventional drying was developed to coincide with the commercialization of raisins and the need to meet the consumers' demands. Grapes are placed in dehydration tunnels for at least 24 h, using air circulation at controlled temperature [17]. This method confers low labor costs and can be easily controlled, and results in products of superior quality however it requires high energy generation [26,34]. Thus, new technologies and methods have been developed to mitigate the drawbacks of conventional air drying in chambers and accelerate the moisture diffusion rate, including microwave drying, vacuum pulsed drying, infrared drying, etc. [18,19]. For instance, microwave drying exhibits reduced energy consumption, enhanced dehydration rate thus less time to obtain the final product [35]. Likewise, combination of methods (microwave, infra-red, and conventional drying) has been also studied aiming to improve the final quality of the products. Indeed, as Benlloch-Tinoco et al. [17] noted the combination of advanced and alternative processes entails a reduction on the impediments observed on the nutritional and functional characteristics of the final product impaired by drying.

Drying of the grapes does not constitute the final stage of processing. Post-drying treatments include washing of the raisins, stem, and other materials removal, packaging and storage [36]. The conditions of packaging and storing of raisins may also affect the final quality of the product, with entomological and microbiological infections also being the dominant concerns.

All processing steps of grapes to formulate raisins, along with storage and packaging, constitute crucial factors that affect the final quality of the product. On top of that, a dynamic interaction is established among these parameters and the variety of grape and culture conditions before harvesting (e.g., sun exposure during maturation).

Color has been employed as an indicator of the chemical pre-treatment effects on raisins in previous studies, whereby it has been widely acknowledged that sulfite treatments entail raisins with lighter color. This could be attributed to the inhibition of PPO activity thereby the prevention of non-enzymatic browning. Carbonic maceration using CO_2-rich atmosphere on red globe grapes led to a more accepted color for raisins [37]. Raisins demonstrating lighter color, thus, highest quality, were also obtained via dipping in alkaline solution at 40 °C [38]. Likewise, Doymaz and Altıner [39] tested a potassium carbonate and olive oil solution, and compared the raisins with untreated samples, observing lighter color in the treated ones. It was speculated that potassium carbonate acted on the fatty acids of the waxy coat of the grape via saponification reactions producing lighter color. In another study, pre-treatment with K_2CO_3 and ethyl oleate resulted in brown coloring at all the dipping times and temperatures evaluated, while it was stressed out that dipping temperatures higher than 40 °C resulted in lighter brown color [40]. When abrasion was tested as a physical pre-treatment for two different grape varieties, darker color was developed in the treated raisins, however no significant differences were noted on the texture analysis [28].

Changes in texture, color, taste, and nutritional value are known to be impaired by any type of dehydration process [17]. Thus, the different subcategories of drying effects, associated with the quality and consumers' acceptance, include physicochemical, microbiological, nutritional as well as sensory, characteristics.

During open sun drying varying temperatures prevail, whereby grapes are directly exposed in high temperatures, causing color, texture, and flavor changes, because of the light-sensitive compounds [18]. Further, the action of PPO and non-enzymatic reactions (e.g., Maillard reactions) entailed the accumulation of brown and black pigments that lead to darker color. Maillard reactions relate also to an increase in hardness owing to harder structures formed [41]. On the other hand, solar drying can also result in color variations and odor modifications. Mahmutoğlu et al. [42], evaluated the outcome of different pre-treatment solutions and drying methods, (i.e., sun and solar), on drying rate and color. Raisins treated with alkaline ethyl oleate solution yielded a lighter color compared to the untreated ones, whereas it was suggested that the reduction of drying time was related to the reduction in brown coloring [42]. Improved quality deriving from Thompson seedless variety were observed using solar drying with a transparent cover [43]. In the context of micronutrients, a comparison of sun drying to microwave vacuum dehydration, indicated an increased concentration of vitamin C, thiamine, and riboflavin in the microwave-vacuum treated raisins [44]. Zemni et al. [45] also noted that greenhouse-dried raisins indicated higher quantities of Ca, Mg, and Na compared to conventional hot air drying.

The majority of studies that evaluated various drying methods and their effect on color, have unambiguously concluded that solar, conventional and (recently) microwave drying result in lighter color compared to sun drying [45,46]. This could be attributed to the reduction in drying time; this shorter time prevents color degradation and subsequent browning caused by enzymatic or non-enzymatic reactions. Shrinkage, on the other hand, refers to the reduction in size or volume of the product, deriving from the loss of water. Khiari et al. [19] refers to the parameters that relate to texture; hardness, stickiness, moistness, elasticity, cohesiveness, and chewiness. Studies investigating the effect of drying methods often implement sensory analysis to evaluate palatability, acceptability and preferences of the consumers. For instance, a negative correlation to consumers' acceptance was perceived for firmness, in the case of Italia grapes were dehydrated using varying temperatures and times, via central composite design [47]. This observation is linked to longer drying times that entail an increase in hardness, thus negatively affecting consumers' acceptance. Aroma of the final product associates volatile and non-volatile compounds, that also correlate with the taste of the raisin.

Dehydration process entails different moisture levels and modifies water activity (a_w) thus the proliferation of microorganisms is usually hindered. Nonetheless, drying does not constitute the final step of processing, thus storage and in some cases rehydration of raisins might trigger the growth of microorganisms, in particular fungi. Likewise, the most common contaminants in raisins relate to ochratoxin A (OTA). The European Commission has established a maximum level of 10 μg/kg for OTA in dried vine fruit. The occurrence of OTA in dried grapes results from the contamination by certain mold species of *Aspergillus* spp. The presence and spread of the latter is influenced by humid weather during grapes production, lack of pruning and humid weather during drying. Therefore, good agricultural practices, and especially application of controlled and suitable drying and storage conditions, comprise the most important preventive measures. Several studies have examined the total colonies count and individual yeast and fungal strain counts to evaluate the effect of drying technologies on microbiological spoilage [45].

Significant research interest has been devoted to the changes in polyphenol and antioxidant content, however as they have been extensively reviewed in previous studies [18,19], the present review will target specifically indigenous Greek varieties and their antioxidant compounds in a subsequent section.

3. Greek Dried Grapes: Source of Bioactive Compounds

3.1. Nutritional Profile and Bioactive Compounds

For the production of Greek dried grapes, the dominant applied method is traditional open sun drying, where grapes are layered on trays on the ground and left to dry until the required moisture content (less than 16%). As an exception, Sultanina from Crete might be produced via conventional air drying on some occasions, whereas sulfite pre-treatment might also be applied [24]. However, Corinthian currants are obtained via sun drying, although shade drying is also emerging as an alternative drying method abandoned from producers for many years [23]. A preceding study, evaluated sun (open and under shade) and industrial drying operation on Sultana seedless and black currants, indicating that forced air drying enhanced drying rates in both types of grapes [48]. Equally, it was stressed that industrial drying improved the final product quality in comparison with solar dehydration. Recent studies, focusing to undertake the effect of drying on currant composition and nutritional value will be listed below.

Grapes, raisins, and currants constitute a significant source of micro- and macronutrients, including sugars, vitamins, minerals, and fiber but they also deliver a diversified range of bioactive compounds (e.g., polyphenols and carotenoids). The latter compounds are non-nutritional, but contribute in health wellness and longevity through the prevention and control of non-communicable diseases, particularly in genetically predisposed populations [11].

Raisins content includes more than 62% of sugars, with the monosaccharides glucose and fructose being in almost equal proportions, and lower amount of sucrose [24]. Therefore, raisins constitute an easily absorbed form of energy, providing moderate Glycemic Index (GI). It is worth noting that a health claim concerning "Corinthian raisins" and the ability to lower blood glucose rise after their consumption, has been already submitted for EFSA's approval [49].

Currants have received significant attention, as they are nutrient dense fruit with a high concentration in bioactive compounds, along with the absence of total fat and cholesterol. An indicative composition of selected nutrients in indigenous Greek currants (Corinthian and Zante currants) is presented in Table 1. Similar to raisins, currants provide a good source of dietary fibers, minerals like calcium, iron, magnesium, phosphorus, and potassium along with vitamin B complex, whereas demonstrating low amount of sodium [22,24]. For instance, Bennett et al. [31] evaluated the micronutrient and folate (vitamin B9) content of several Australian and imported dried fruit. Zante currants were also included, exhibiting higher calcium concentration when compared to other varieties, iron levels deemed also significant, although folate quantity was lower compared to Australian currants.

Table 1. Composition of Greek currants (values expressed per 100 g of product).

	Zante Currant [1]	**Corinthian Current** [2]
Nutrient	Value per 100 g	Value per 100 g
Water (g)	17.6	NR [3]
Protein (g)	3.43	2.5
Total lipid (g)	0.22	0.4
Carbohydrate (g)	76.98	77.5
Sugars (total, g)	62.28	NR [3]
Fiber (total dietary, g)	4.4	6.7
Minerals		
Calcium (mg)	88	10
Iron (mg)	1.88	4
Magnesium (mg)	36	30
Phosphorus (mg)	99	180
Potassium (mg)	777	710
Sodium (mg)	43	NR [3]
Zinc (mg)	0.37	NR [3]

[1] https://fdc.nal.usda.gov/fdc-app.html#/food-details/171724/nutrients [22]. [2] Vasilopoulou et al., 2014 [24].[3] NR: not reported.

The final composition of currants comprises a dynamic modification deriving from multiple variables, including cultivation and weather conditions (e.g., irrigation, sun exposure) among others. Likewise, Nikolidaki et al. [50] studied the simple sugar profile of Corinthian currants, over three consecutive crop years. Fructose, glucose, sucrose, maltose, and total sugar content along with moisture, ash, fat, and protein content were evaluated and related to cultivation conditions (altitude). The authors noted that differences in the composition were indeed observed, however, they were not significantly related to the final product quality. Average values obtained for moisture, fat and protein were found 13.8 ± 0.5%, 0.43 ± 0.06% and 2.2 ± 0.4%, respectively. Equal amounts of fructose and glucose were measured, whereas sucrose and maltose were in low levels. On top of that, as previously noted, dehydration method of currants could potentially affect composition. Panagopoulou et al. [23] studied sun and shade drying and further analysed the phytochemical and sugar composition over three consecutive crops. It was evidenced that individual and total sugar profile was not significantly altered from the drying method. In a following study, Panagopoulou et al. [25] presented an assessment of the vitamin B content of Corinthian raisins, within consecutive cultivation periods. Vitamin B_3 (7.7–28.2 mg/kg) exhibited the higher concentration, followed by B_6 (2.7–3.7 mg/kg), B_1 (1.9–2.2 mg/kg), and B_2 (1.0–1.5 mg/kg). Similarly, apart from B_3, the differences between regional cultivations, altitude and crop years were not deemed significant, as all samples contained thiamine, thiamine pyrophosphate, nicotinamide, nicotinic acid, pyridoxamine and pyridoxine.

Among the high nutritive components of currants, the phenolic content has attained notable scientific interest. Phenolics constitute a group of paramount importance within functional compounds and refer to anthocyanidins, catechins, flavanones, flavones, lignans, and tannins [11], several of them demonstrating significant antioxidant activity. Antioxidant compounds act to neutralize the free radicals and reactive oxygen species (ROS) in cells that occur from cell redox imbalances. The phenolic content and antioxidant activity of grapes and wines has been widely evaluated, while raisins are on the spotlight of recent studies [10]. Likewise, research has been performed on the changes in the phenolic content occurring during drying process for raisins [27,51]. For instance, Olivati et al. [27] reported that pre-treatment with olive oil applied in BRS Morena grapes, resulted in higher amount of anthocyanins and proanthocyanidins, compared to the untreated samples. An increased concentration of phenolic acids and flavonoids, and more specifically rutin, kaempferol-hexoside, quercetin, and isoquercitrin, was observed during sun drying of Argentinian grapes [51]. It is generally acknowledged that drying processes entail higher concentrations of total phenolics, anthocyanins and tannins in raisins compared to fresh grapes [36,41]. Likewise, Figueiredo-González et al. [52] mentioned that the raisining process of sun-dried grapes led to increased concentrations of phenolic compounds, such as (+)-catechin, (−)-epicatechin, and procyanidins B_1 and B_3.

With respect to indigenous currant varieties, research has been also conducted to evaluate the content of total polyphenols, individual phenolic compounds and antioxidant capacity (Table 2). Chiou et al. [53] presented the content of simple phenolics and the antioxidant activity of three different sub-varieties of currants, namely, Vostizza, Gulf and Provincial. The concentration of total polyphenols was in the range of 151 mg/100g and 246 mg/100 g currants. Vanillic acid was the principal compound (1.21 ± 0.23 mg/100 g currants) followed by caffeic acid, gallic acid, syringic acid, p-coumaric acid, protocatechuic acid, ferulic acid, and quercetin [53]. In a following study, research was expanded to assess total and individual anthocyanins, total phenolics and antioxidant capacity of the same sub-varieties over consecutive year crops [54]. The authors reported for the first time, the identification and quantification of up to five anthocyanidin-3-O-glucosides in Greek currants. Vostizza currants exhibited the highest total anthocyanins concentration and lower total phenolics and antiradical activity. Noteworthy, the authors observed statistically significant differences for some compounds, (e.g., malvidin-3-O-glucoside content), between different crop years and regions, indicating how modifications in anthocyanins content could be attributed to cultivation conditions and process operations. Kaliora et al. [55] studied the antioxidant properties of methanolic extracts deriving from several indigenous sub-varieties of dried grapes, namely, Nemea, Messinia, and Vostizza currants and Cretan Sultanas. The tested extracts demonstrated significant DPPH activity, with Nemea currants exhibiting the highest value, whereas Vostizza and Messinia currants presented the highest total polyphenols (1.223 ± 0.05 and 1.205 ± 0.02 μg of caffeic acid/500 μg of product respectively). As mentioned in a previous section, Panagopoulou et al. [23] provided a comparison between sun and shade drying and their effect on phytochemical content. Drying under shade entailed higher total phenolic, flavanol and anthocyanin content, highlighting the advantages of the latter method versus the conventional one currently applied. Narendhirakannan et al. [56] provided an evaluation of the antibacterial, antioxidant and would healing properties of several plant extracts, including Zante currant, which exhibited an antioxidant activity of 59.88 μg/mL, comparable to the standard ascorbic acid (58.82 μg/mL). Moreover, the antimicrobial activity of black currants was found to be among the highest against all microbial strains tested. Discarded Zante currants, deriving as a by-product during processing, have been also characterized for their ability to maintain their high phenolic content, which was determined up to 3.36 mg/g of dry currant depending on the extraction method [57].

Table 2. Phenolic content of different Greek raisins and currants.

Sub-Varieties	Region in Greece	Total Phenolic Content (mg/g) [a]	Reference
Vostizza	northern Peloponesse	2.446 [b]	[55]
Vostizza	northern Peloponesse	1.55–2.46	[53]
Vostizza	northern Peloponesse (conventional cultivation)	2.30–2.55	[54]
Vostizza	northern Peloponesse (organic cultivation)	2.61–2.66	[54]
Messinia	western Peloponesse	2.41 [b]	[55]
Cretan Sultanas	Crete island	0.662 [b]	[55]
Nemea	northern Peloponesse	0.592 [b]	[55]
Provincial	western Peloponesse	2.01–2.05	[53]
Provincial	western Peloponesse	2.28–2.64	[54]
Provincial	Zante island	2.11	[53]
Provincial	Zante island	2.17–2.43	[54]
Gulf	northern Peloponesse	1.67–1.90	[53]
Gulf	northern Peloponesse	2.33–2.35	[54]
Zante (discarded during processing)	Zante island	1.92–3.36	[57]

[a] Total phenolic content was expressed as gallic acid equivalents and determined by Folin–Ciocalteu assay. [b] Total phenolic content was expressed as caffeic acid equivalents and determined by Folin–Ciocalteu assay.

Collectively, the aforementioned studies elucidate the significance of total and individual polyphenols and their antioxidant capacity from Greek dried grapes, indicating that their consumption could confer several health benefits as they will be discussed in the following section.

3.2. Health Benefits of Greek Dried Grapes (In Vitro, In Vivo, and Clinical Trial Studies)

The nutritional value of raisins and currants has been unequivocally demonstrated following several studies, implementing both in vitro and in vivo experiments but also clinical trials (Table 3), with respect to their composition but also their health benefits, addressed to healthy people, athletes, and patients suffering from various diseases [58,59]. Raisins comprise an important source of boron, a trace element that relates to bone health, prevention of arthritis and osteoporosis in postmenopausal women [60]. Boron might also interact with normal functions including enzyme reaction, cell membrane function, and hormone metabolism, and it is also required for brain function [61].

Apart from the advantages mentioned above, raisins constitute a rich source of fructooligosaccharides, specifically fructans, which exhibit prebiotic effect on modulation of the gut microbiota. For instance, Wijayabahu et al. [62] conducted a pilot feeding study, where volunteers consumed sun dried raisins three times per day for fourteen days. Analysis of fecal samples indicated that overall microbiota composition was not substantially altered, although the inclusion of raisins resulted in significant increases in targeted taxa, specifically *Faecalibacterium prausnitzii*, *Bacteroidetes* sp., and *Ruminococcus* sp., which have the potential to exert health benefits [62]. Likewise, diets rich in fiber have been associated with a reduction in the risk of CVDs, constipation, diabetes, colon cancer, and obesity [60]. Fiber content in dried fruit along with phytochemicals like phenolic acids, are speculated to contribute in the reduction of glycemic response [63]. Guidelines directed to people diagnosed with type 2 diabetes or predisposed individuals include a low glycemic load diet. Raisins have a medium-to-low glycemic index and could stimulate the mechanisms associated with insulin levels, blood pressure, and satiety control [64]. Viguiliouk et al. [63] performed a randomized acute-feeding trial to evaluate the effect of dried fruit including raisins and sultanas, on postprandial glycemia, whereby a reduction in the glycemic response was suggested whereas raisins demonstrated a GI of 54.7 [63]. In another study, Zhu et al. [64] also included raisins among other dried fruit, as a substitute to high carbohydrate foods (e.g., white bread) to investigate blood glucose concentration. The study suggested that moderate amount of fructose in dried fruit could mitigate the excess rise in blood glucose, and confer a positive effect on postprandial glycemic control, without changing the total carbohydrate intake.

The inclusion of raisins in the diet has been also proposed to confer benefits on the prevention of neurodegenerative diseases. Gol et al. [61] assessed the protective effect of raisins (currants) against deficits in spatial memory and oxidative stress in animal models of Alzheimer disease. Study outcomes revealed that treatment with raisin mediated an increase in spatial memory, thus implying a neuroprotective effect in animal models. Similarly, Ghorbanian et al. [65] suggested that raisin consumption in aging rats conferred an increase in blood antioxidant levels and enhanced cognitive function, thus positively affecting spatial memory.

Significant research has been also conducted on indigenous Greek sub-varieties of dried grapes and the potential to confer health benefits. To evaluate the bioavailability of the phytochemicals of Corinthian raisins and also their postprandial effect on serum resistance to oxidation, Kanellos et al. [66] conducted a feeding trial including fifteen healthy volunteers and measured serum oxidizability, plasma total polyphenol content and oleanolic acid. Identification of sixteen phytochemicals and oleanolic acid in plasma evidenced the impact of Corinthian raisins antioxidants in in vivo experiments, thus their bioavailability. The postprandial effect of Corinthian raisin consumption was also studied by Kaliora et al. [67], whereby glucose and fructose were assessed in the context of hormones controlling appetite regulation. A crossover study with ten healthy volunteers demonstrated that ghrelin and also ghrelin/obestatin ratio was lower in raisins when compared to glucose, thereby speculating that Corinthian raisin consumption could prove beneficial in appetite regulation.

Likewise, Kanellos et al. [68] investigated the metabolic responses (i.e., glycemic and insulinemic) following the consumption of Corinthian raisins on healthy volunteers and patients with type 2 diabetes mellitus. A reduction in both responses was demonstrated after Greek raisins inclusion opposed to glucose as reference. GI was found in the range of 66.3 ± 3.4, suggesting that raisin inclusion in the diet could prove beneficial in postprandial response both for healthy population and patients [68]. To further elucidate the effect of Corinthian raisins consumption and the effect on patients with diabetes, Kanellos et al. [69] conducted a two-armed, randomized, controlled intervention trial, whereby blood pressure, fasting glucose, glucated hemoglobin (HbA1c), lipid peroxidation, high-sensitivity C-reactive protein, antioxidant status, and cytokines in patients with type 2 diabetes mellitus were included as evaluation factors along with phenolic compounds in blood plasma. The authors reported that Corinthian raisins intake could mitigate diastolic blood pressure and entailed an increase in total antioxidant potential compared to the baseline, thus evidencing health potential for patients with type 2 diabetes.

Several pathological conditions including carcinogenesis and atherosclerosis are linked to oxidative stress, whereas specifically the oxidation of low-density lipoprotein (LDL) contributes in the pathogenesis of atherosclerosis (Yanni et al., 2015). High blood pressure also exhibits an increased risk factor for cardiovascular disease. The consumption of foods rich in polyphenols has been implied to support the prevention of coronary heart disease and some types of cancer but also to prevent LDL oxidation [53]. The impact of Corinthian currants (*Vostizza*) on atherosclerosis and plasma phenolics was investigated by Yanni et al. [70], using hypercholesterolemic rabbits that resemble the development of the human disease in the early stages. Plasma lipids, glucose, and hepatic enzymes were evaluated along with the identification and quantification of phenolic compounds in plasma. The authors reported that atherosclerotic lesions were mediated and, also, that oxidative stress was decreased. A regulatory mechanism in gut level was also speculated, followed by the observation that inclusion of currants entailed a reduced absorption of phenolics.

Kanellos et al. [71] tested the hypothesis whether Corinthian raisins consumption in between meals would prove beneficial on clinical features and biological markers (i.e., inflammation, oxidative stress, and arterial function) in healthy smokers. An open-label randomized controlled intervention was conducted, but interestingly the beneficial impact of reduction in blood pressure, total cholesterol and LDL-cholesterol was noted only on female participants.

Prevention of carcinogenesis through diet modification exhibits a strategy widely applied. To this end, Kaliora et al. [72] studied the gastric cancer preventive function of methanolic extracts obtained from Greek raisins (Vostizza, Nemea, Messinia, and Cretan Sultanas). The ability to hinder cell proliferation, induce apoptosis and prevent inflammation was included and the results indicated an attenuation in cell growth and stimulation of cell death, suggesting the potential to prevent gastric carcinogenesis. In a subsequent study, Kountouri et al. [16] implemented Corinthian currants and Sultanas to investigate the effect on human colon cancer cells. The anti-radical activity of methanolic extracts in vitro was well established through the inhibition of cell proliferation, an outcome that further elucidated the preventive activity of raisins phenolics on colon cancer cells.

One of the emerging public health issues is non-alcoholic fatty liver disease (NAFLD) and steatohepatitis, linked with obesity and type 2 diabetes and oxidative stress. Within this context, Kaliora et al. [73] employed a pilot randomized controlled clinical trial using Corinthian raisins as snack to study the effect on oxidative stress and inflammation markers in NAFLD patients with non-significant fibrosis, whereby the beneficial effect was evidently shown, via improvements in fasting glucose, inflammation and fibrosis stage.

Moreover, one of the recent research studies employed Corinthian currant as pre-exercise ingestion supplement, tested during prolonged cycling. It was evidenced that Corinthian currant conferred the same beneficial effect as a glucose-drink (carbohydrate supplementation) in regulating post-consumption blood glucose levels, a factor related with enhanced performance [74].

Table 3. Health benefits related with the consumption of raisins, including Greek varieties and sub-varieties.

Raisin Variety or Sub-Variety	Potential Effect	Trial Conditions	Primary Findings	Reference
Dried raisins and Sultanas	Decrease postprandial glycemia	Human study: 10 healthy volunteers 18–75 years, 25 g raisins to displace half of the available carbohydrates in white bread	The combination of dried fruits with high glycemic index foods by displacing available carbohydrate reduces the glycemic response of these foods	[63]
Raisins (*Vitis vinifera* Linn.)	Decrease postprandial glycemia	Human study: 11 healthy volunteers 18–25 years, 75.2 g raisins	The combination of raisins with nuts prevented hyper- or hypo-glycaemia episodes	[64]
Corinthian	Decrease postprandial glycemia	Human study: 15 healthy volunteers 20–30 years and 15 volunteers with type 2 diabetes mellitus 55–68 years, 74 g raisins or 50 g glucose (reference food)	Raisins consumption decreased glycemic and insulinemic responses compared to reference food	[68]
Corinthian	Bioavailability of phytochemicals	Human study: 15 healthy volunteers 20–40 years, 144 g raisins	The bioavailability confirmed by the identification of several phytochemicals in plasma	[66]
Corinthian	Improve biological markers of patients with type 2 diabetes mellitus (T2DM)	Human study: 48 volunteers with T2DM 40–65 years, 36 g raisins daily, 24 weeks	Raisins consumption decreased diastolic blood pressure and increased plasma antioxidant capacity	[69]
Dried raisins	Appetite regulation	Human study: 10 healthy volunteers 26.3 ± 0.8 years, 74 g raisins or 50 g glucose (reference food)	The hormones ghrelin and also ghrelin/obestatin ratio was lower in raisins than in glucose consumption, which led to a balanced appetite	[67]
Corinthian	Improve biological markers of healthy smokers	Human study: 10 healthy volunteers smoking > 10 cigarettes/day, 20–40 years, 90 g raisins daily, 4 weeks	Blood pressure, total cholesterol and LDL-cholesterol were reduced only in female participants. The quantity of raisins was insufficient to cause a significant effect on smokers	[71]
Vostizza, Nemea, Messinia and Cretan Sultanas	Prevention of gastric cancer	In vitro study: methanolic extracts from raisins (1:10, solid:liquid) were tested to AGS human epithelial cells from stomach	Raisins' extracts inhibited cell proliferation, induced cell death and prevented inflammation	[72]
Corinthian and Sultanas	Prevention of colon cancer cells	In vitro study: methanolic extracts from raisins (1:10, solid:liquid) were tested to HT29 human epithelial cells from colon	Raisins' extracts inhibited cell proliferation and exhibited anti-radical activity	[16]

Table 3. *Cont.*

Raisin Variety or Sub-Variety	Potential Effect	Trial Conditions	Primary Findings	Reference
Corinthian	Improve biological markers of patients with non-alcoholic fatty liver disease (NAFLD)	Human study: 50 volunteers with NAFLD disease, around 50 years, 36 g raisins daily, 24 weeks	Minimal dietary changes in patients of non-significant fibrosis resulted in improvements in fasting glucose, inflammation and fibrosis stage	[73]
Corinthian and Vostizza	Reduce atheroma development	Animal study: 30 white rabbits, diet supplemented with 10% raisins or 10% raisins and 0.5% cholesterol for 8 weeks	The atherosclerotic lesion formation was retarded in hypercholesterolemic rabbits	[70]
Corinthian	Raisins as pre-exercise supplement instead of a glucose drink	Human study: 11 healthy volunteers, 21–45 years, 1.5 g carbohydrates per kg of body weight, 30 min before exercise	Raisins were equally effective to the glucose drink	[74]
Sun-dried raisins	Improve athletes' performance	Human study: 10 males endurance-trained cyclists & triathletes, g raisins during a 10-km cycling time trial	Improvement in performance following a pre-exhaustive bout of exercise and improved Hedonic scores, which implies the viability of an alternative source of carbohydrate	[58]
Sun-dried raisins	Modulation of gut microbiota	Human study: 13 healthy volunteers 18–59 years, 28.3 g raisins (contain 2 g of dietary fiber) daily, 14 days	The population of beneficial bacteria was increased (*Faecalibacterium prausnitzii*, *Bacteroidetes* sp. and *Ruminococcus* sp.) and opportunistic pathogens were decreased (*Klebsiella* sp.)	[62]
Sun-dried black raisins (Maviz)	Neuroprotective	Animal study: 12 old rats, 6 g raisins per day for 90 days	Spatial memory was improved and cognitive and motor function were promoted	[65]
Sun-dried black raisins	Neuroprotective	Animal study: 24 rats with Alzheimer's disease, 6 g raisins per day for 60 days	Spatial memory was improved	[61]

Retrospectively, the protective effect and the benefits of raisins and particularly indigenous Greek currants, on biological markers linked with cardiovascular and degenerative diseases, have been evidenced via clinical and medical studies (Figure 2). Phytochemicals constitute compounds of paramount importance acting on metabolic activities of humans that regulate homeostatic mechanisms. Epidemiological research has shifted towards elucidating the underlying mechanisms and the correlation between functional compounds, nutrition, and genetic diversity. Evidently, it is advocated that diet modification towards a healthier lifestyle prevails as the initial strategy that relates with the alleviation or prevention of disease. Development of functional food products that will include bioactive components could provide an alternative approach to administer bioactive compounds through dietary intervention.

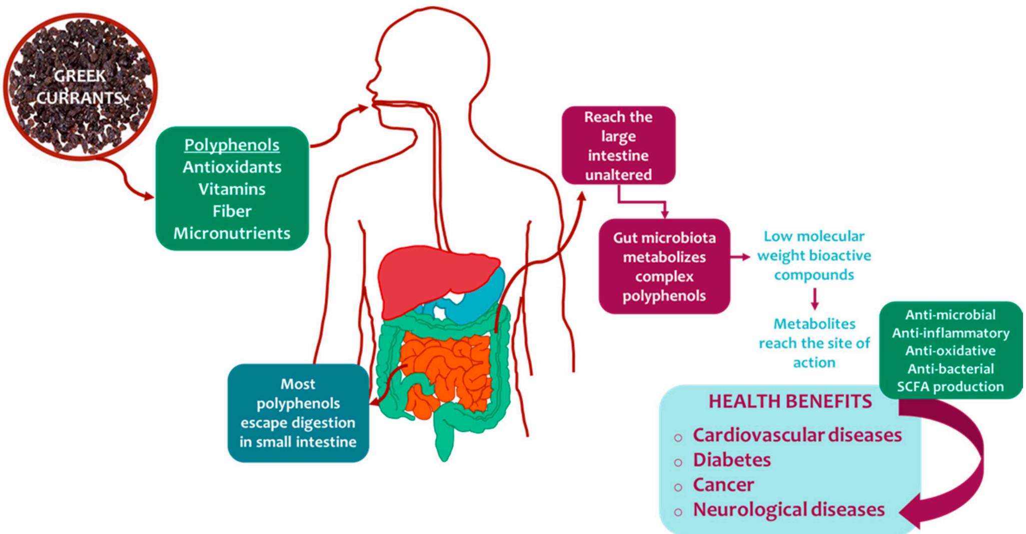

Figure 2. Potential health benefits from indigenous Greek dried grapes consumption with specific focus on polyphenols.

4. Development of Functional Food Products

Functional foods constitute conventional foods, and include compounds that confer health benefits on the body, as well as foods enriched with such ingredients. The growing consumers' consideration prompted the development of functional foods eliciting the ability to treat or prevent several diseases. Likewise, the shift towards a healthier nutrition regime emerged as an issue of paramount importance worldwide, placing food industry in the forefront of functional food product development. Therefore, the development of food products with functional properties has been extensively reviewed in the literature, elaborating the issues that concern the opportunities but also the challenges of manufacturing foods with possible health claims, along with the use of renewable resources and emerging technologies to produce them [75–77].

As described in the previous sections, despite the particular attention that has been assigned to the functional properties of raisins, their utilization in novel food formulations was overlooked the last decades (Table 4). Thus, recently raisins have been employed in the formulation of several products within the context of conveying health benefits deriving from their bioactive compounds. Notably, the inclusion of raisins in newly formulated foods will potentially entail modifications in the structural and textural properties of the final product, thereby the latter constitute a significant parameter to be evaluated together with sensory characteristics.

Table 4. Trends in food product development using raisins or raisins products.

Type of Raisin-Based Substrate	Food Product	Food Properties	Reference
Raisin juice concentrate and raisin paste	Bread	Increased shelf life, due to the antifungal and antibacterial properties	[78]
Concentrate raisin juice and dried raisin juice	Gluten-free bread	Improved loaf volume, color and increased crust and crumb softness	[79]
Concentrate raisin juice and dried raisin juice	Bread and durum wheat flour dough	Improved loaf volume, flavor, color, increased crust and crumb softness	[80]
California raisins, Sultanas and Zante currants	White bread	Increased bread volume, gumminess, brittleness and hardness	[81]
Raisins	Cereal bars	Increased phenolic content and antioxidant activity	[82]
Raisins	Ready to eat cereal	Increased nutritional profile	[83]
Raisins	Health drink	Lower carbohydrate content	[84]
Corinthian raisins	Enriched probiotic yogurt	Improved probiotic viability, sensory and nutritional profile, and syneresis phenomenon	[85]
Raisin puree	Coconut milk yogurt	Improved probiotic viability and nutritional profile	[86]
Concentrate raisin juice	Chocolate ice-cream	Improved flow properties (highly creamy and gummy) and melting resistance, balanced chocolate flavor	[87]

Bread and bakery products comprise a wide range of products with universal consumption worldwide alongside nutritional value and sensory properties. Utilization of raisins in bread, cereal products and snacks has been long applied, as they can substitute for synthetic preservatives, due to the propionic acid and phenolic compounds they contain, thereby increasing the shelf life of bakery products [78]. Likewise, bread has been implemented in several investigations in the context of new formulations, to assess the implementation of raisin products. For instance, Wei et al. [78] used raisin juice concentrate and raisin paste in bread formulations to evaluate the antimicrobial effect, indicating the strong mold retarding properties of raisins, entailing a subsequent extension in the shelf life of the final product. Raisin juice was also applied as sucrose substitute in combination with gluten-free flour to evaluate changes in baking properties sensory characteristics [79]. Enhanced loaf volume and color in the final product were observed with raisin juice in both concentrated and dried form, whereas sensory analysis suggested the acceptance of bread containing raisin juice. In a similar manner the effect deriving from the addition of dried raisin juice in bread and durum wheat flour was also studied [80]. Baking and sensory characteristics, textural and dough rheological properties were assessed, suggesting improved volume loaf and shelf life, although sensory analysis demonstrated a preference for the breads made with sucrose. The effect on the quality of dough for white bread (pH, titratable acidity, and fermentation time) was estimated using California raisins, Sultanas and Zante currants [81]. All types resulted in higher bread volume, whereas textural analysis showed higher values for gumminess, brittleness, and harness in comparison with the control sample.

Lara et al. [82] developed cereal bars using raisins or prunes with varying coffee concentrations. The products containing raisins demonstrated the highest antioxidant activity based on the phenolic compounds, thus indicating the potential to mediate oxidative stress. On top of that, the bars with raisins were allocated with high consumers scores during the sensory evaluation test, to supplement their acceptance [82]. In a similar study, the design of a nutrient rich Ready to Eat (RTE) breakfast cereal was presented, using popped pearl millet, popped amaranth, puffed wheat, flax seed, sunflower seeds, raisins, honey, sugar, oil, and water [83]. The nutritional profile and nutritional adequacy were assessed, providing information on total dietary fiber, protein, vitamins, and minerals, whereas the sensory analysis suggested the acceptability of the product compared to commercially available ones.

A novel health drink was prepared including turmeric, black pepper, mango peel, raisins, and almonds and the nutritional value was subsequently evaluated, along with comparing it with currently available health drinks [84]. Bosnea et al. [85] presented the development of a novel probiotic yogurt via the inclusion of fresh apple pieces, dried raisins, and wheat grains supplemented with *Lactobacillus casei*. Results demonstrated the sustained viability of the probiotic strain through storage, along with the acceptance in the context of aroma, flavor, and texture. The latter case study suggested an approach for the implementation of raisins as carrier matrix for probiotics or other functional compounds, thereby establishing the potential for novel functional food formulations. A recent study reported on the physicochemical properties, sensory characteristics and probiotic viability of a coconut milk yogurt generated with the supplementation of raisin puree in varying amounts [86]. The addition of raisin puree entailed a lower protein content, however, higher viscosity and sustained probiotic viability were attained. Overall, coconut yogurt with the higher level of raisin puree enhanced the physical properties but also the acceptance during sensory evaluation.

Soukoulis and Tzia [87] conducted a study to substitute sucrose with sugarcane, grape or raisin molasses in chocolate ice cream. Raisin molasses exhibited improved flow properties and melting resistance. Sensory analysis indicated a combined effect in the context of chocolate taste and creaminess [87], implying a promising potential to replace sucrose and increase the functional profile of ice cream.

5. Future Trends and Perspectives: Raisins and Currants Production within the Bio-Economy Era

The majority of studies on raisins undertook the effect of processing on bioactive compounds but also the health benefits raisins exert, as previously demonstrated. However, raisins and particularly Greek currants were overlooked the past years, regardless the known and documented health benefits. The flourishing consumers' appeal for functional foods has induced an interest on traditional foods that were previously disregarded. As such, Greek currants have been lately implemented in numerous studies with a prosperous intention to reintegrate these products as part of an everyday balanced diet.

Apart from the inclusion of currants in well-established bread and bakery products, to further enhance the nutritional value, currants could serve as a carrier matrix for the fortification of foods with probiotic strains, in a similar approach to previous studies reporting the inclusion of probiotics on dried fruit [88,89]. The composition of currants in fructooligosaccharides, a well-established prebiotic compound, along with probiotic could entail a potential synbiotic effect [90]. Subsequent studies could be directed on investigating also the viability through the passage of the gastrointestinal transit. Likewise, the viability of bacteria versus storage time and temperature could be also implemented. On top of that, textural and sensorial characterization will entail a crucial factor to be determined in order to coincide with consumers' acceptance.

Increased demand for currants will ultimately result in a proportional upturn of waste streams. Currant processing wastewater is mainly composed of sugars, glucose, and fructose, including lower concentrations of nitrogen compounds, lipids, minerals, organic acids, tannins, and pectins [91]. For instance, hot water blanching of currants is accompanied by significant losses in nutritional compounds along with the management of wastewater streams [18]. So far, wastewater treatment of currant-finishing facilities included chemical and physical processes (coagulation, acidification, evapotranspiration, and anaerobic digestion) to reduce chemical oxygen demand (COD) and mitigate the polluting effect, thus enabling reutilization for irrigation [91]. Biological treatment methods were recently reported by Tsolcha et al. [92], where raisin and winery effluents were utilized for the fermentative production of biomass and lipids. The synthesized lipids from cyanobacteria/microalgae consortia, containing saturated and mono-unsaturated fatty acids, were also evaluated as feedstock for biodiesel production. In a following study, winery-raisin wastewater was also used as substrate in mixed microbial cultures using a support matrix as an attached growth system, to produce biomass, lipids, and biodiesel [93]. The authors demonstrated an intracellular lipid content up to 23.2%, suggesting also the suitability for biodiesel production and correspondingly further optimization of the process for industrial-scale implementation.

Inevitably, currant processing facilities will be required to undertake waste stream management schemes to conform with the context of bio-economy. Development of integrated biorefinery concepts to generate value-added products could provide the potential to resolve waste effluent treatment (Figure 3). Several approaches have implemented the utilization of agro-industrial and food residues as onset material to produce multiple products [94]. A more targeted approach for Zante currant side streams valorization as renewable feedstock within a biorefinery scenario was presented by Tsouko et al. [57]. In this case, rejected Zante currants from the processing stage, were employed to yield a sugar-rich extract and a phenolic fraction. Analysis of phenolic compounds exhibited moderate antioxidant activity. The sugar-rich stream was combined with wastewater from all manufacturing stages and further evaluated in microbial bioconversions to generate bacterial cellulose in high concentration (2.76 g L^{-1}). Overall, the development of a novel raisin-based biorefinery concept was evidenced to exploit entirely the capacity of Zante processing side-streams. The study proposed the extraction of phenolic compounds and the formulation of bacterial cellulose as value-added products, that could be reintroduced in food applications. Following previous studies on the production of foods supplemented with antioxidants, these applications could include fermented dairy products, bread and bakery products and fruit juices (Figure 3). Phenolic compounds could exert a potential prebiotic effect on gut microbiota modulation, taking into account the recent modification of the prebiotic definition, designated to also include phenolics and phytochemicals [95,96]. On the other hand, wastewater and the liquid fraction obtained after phenolics extraction could be utilized as nutrient supplement for bioconversion processes (Figure 3). Additionally, sustainable bioprocesses may be inaugurated through the combination of multiple and diversified waste streams, such as cheese whey which is a by-product of cheese industry rich in nitrogen and lactose [97]. Bacterial cellulose was successfully produced also when Corinthian raisin side-streams were combined with cheese whey [98]; however, other value-added biotechnological products of significant importance could also be potentially employed. Process optimization and market analysis could elucidate the identification of end products that could render the designed process economically feasible, considering also the pillar of safety issues that might arise via the implementation of extracts and/or products in functional foods [99]. In any case, it is indisputable that valorizing these streams will result in the development of a holistic approach that will be directed in closing the loop and complying with the pillars of circular economy.

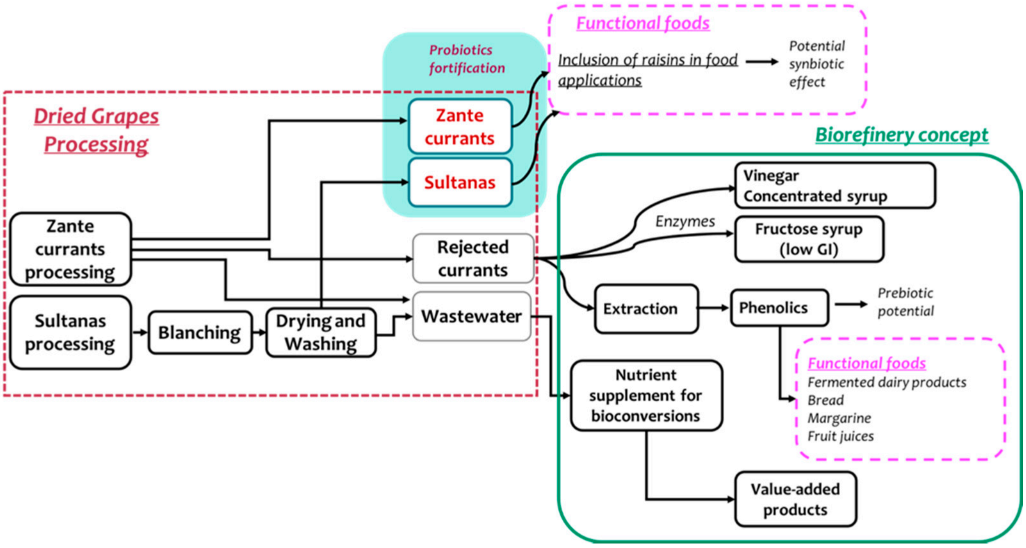

Figure 3. A holistic approach for Zante currants and Sultanas production along with functional foods development and high-value products via the development of a biorefinery concept.

6. Conclusions

Diet regime modification towards healthier choices to prevent illness has emerged on consumers' perception, entailing an analogous increase on the demand of functional foods. As such, Greek currants constitute an overlooked product that could be further enhanced, within the context of promoting and reintroducing traditional superfoods to elicit health benefits and improve longevity. Recent studies on indigenous Greek dried grapes were either directed to elucidate the health benefits their consumption could confer or on the different processing methods and the effect on the final product. Nonetheless, it can be postulated that Greek currants could be implemented in novel formulations of functional food products that will administer bioactive compounds via the utilization of currants as carrier matrices. On top of that, it is crucial to ensure that these processes will be sustainable and conform with the foundations of circular economy. Thereby, a conceptual currant processing facility could be designed to consolidate on-site both the processing of the onset material and side-streams management. The latter could entail the production of value-added products to be re-introduced in the development of novel functional foods with enhanced nutritional value deriving from the nutritive compounds of currants. To benefit from these, integration on already existing manufacturing plants could reinforce the value of the product, induce future investments and also foster regional small scale producers.

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